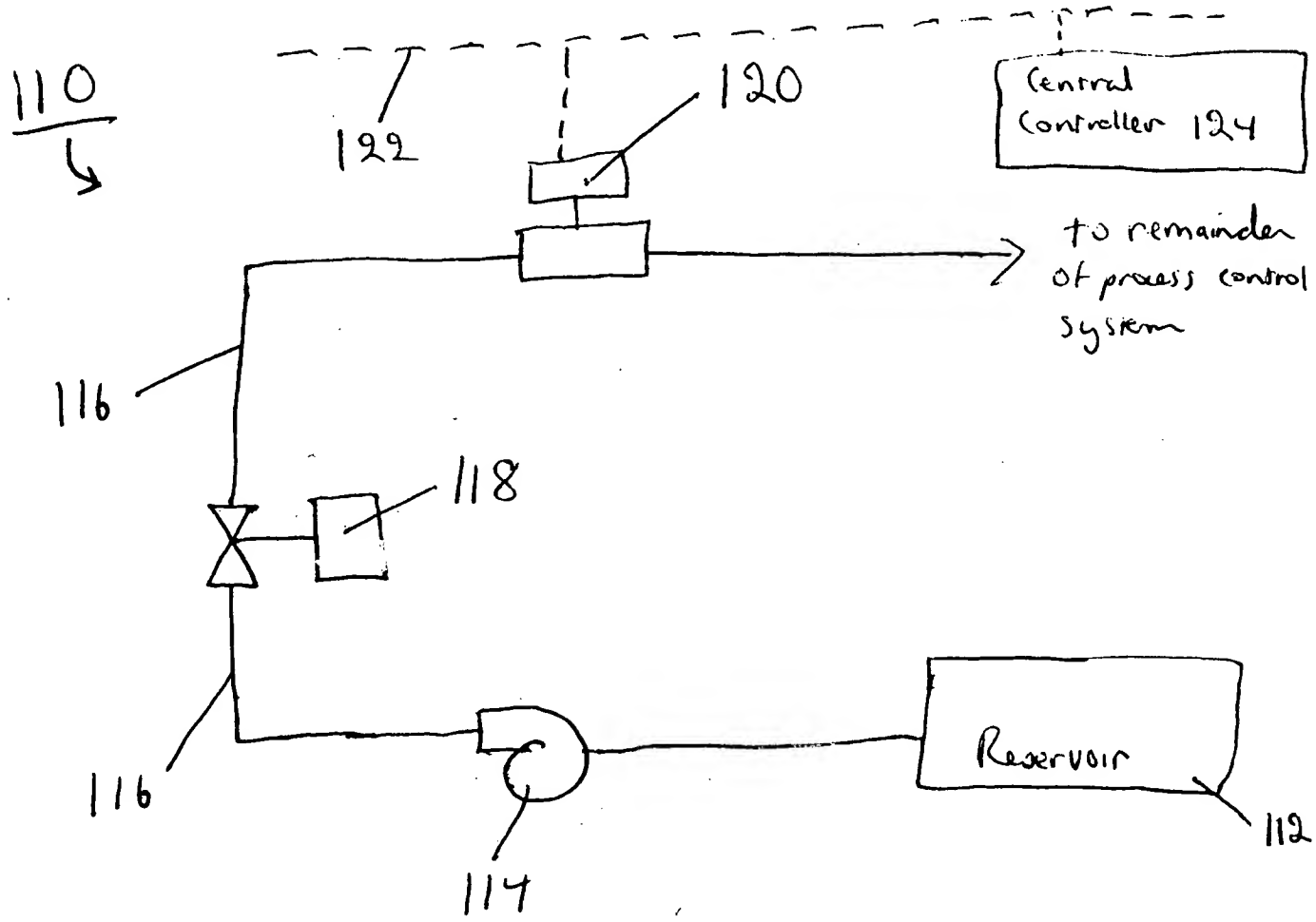


Figure 1

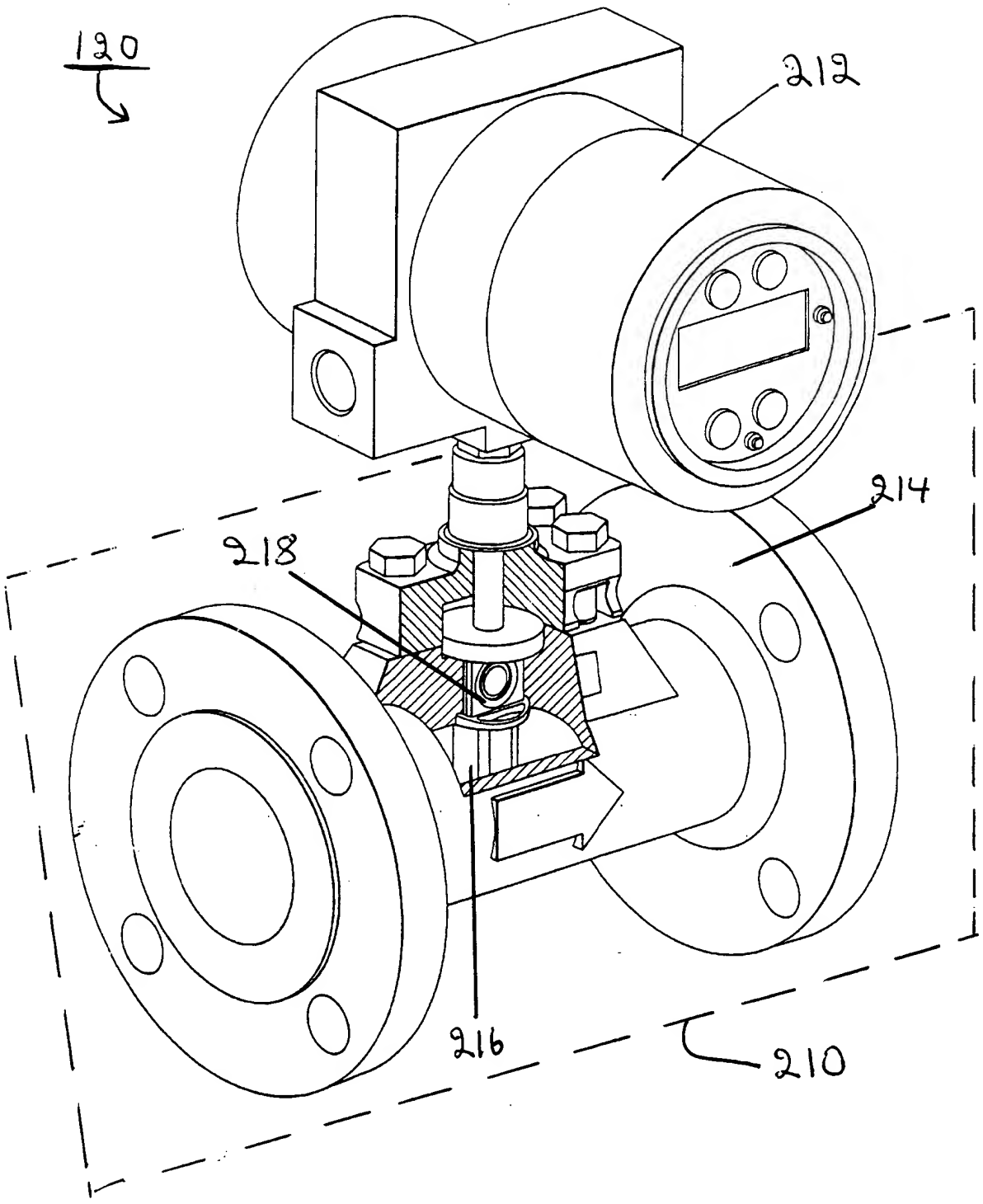


Figure 2

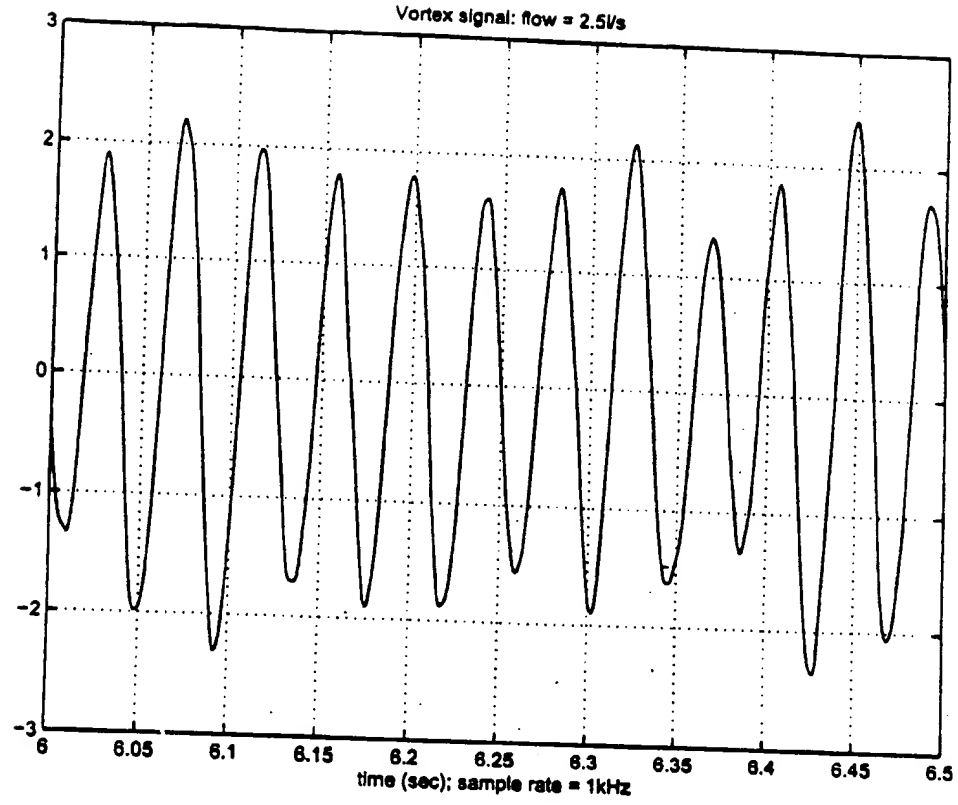

Vortex signal: flow = 2.5l/s
3
2
1
0
-1
-2
-3
6
6.05
6.1
6.15
6.2
6.25
6.3
6.35
6.4
6.45
6.5
time (sec); sample rate = 1kHz

Figure 3a

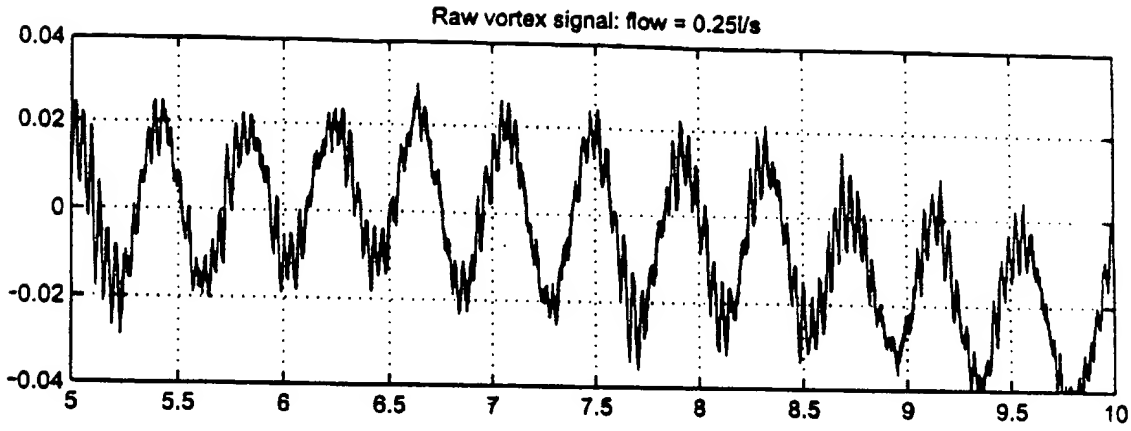


Figure 3b

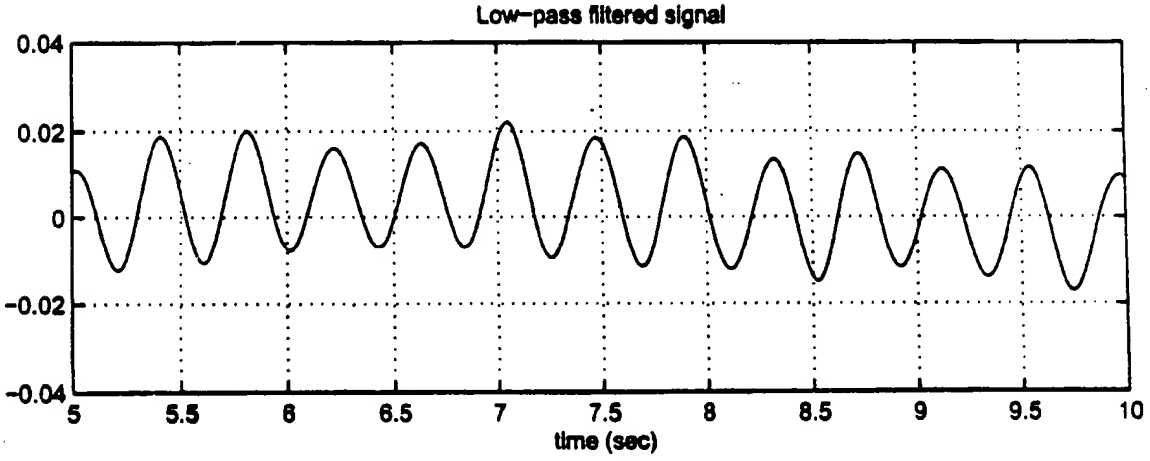


Figure 3c

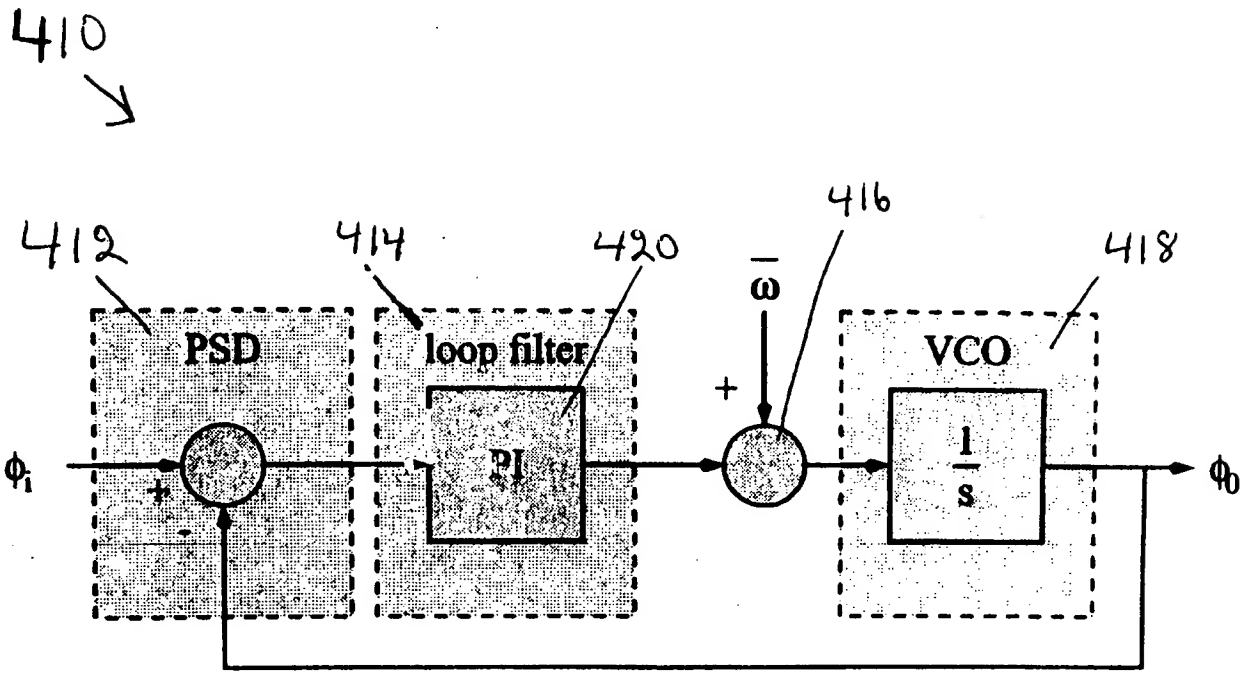

410
412
414
420
416
418
PSD
loop filter
VCO
$\bar{\omega}$
+
ϕ_i
+
-
$\frac{1}{s}$
ϕ_0

Figure 4

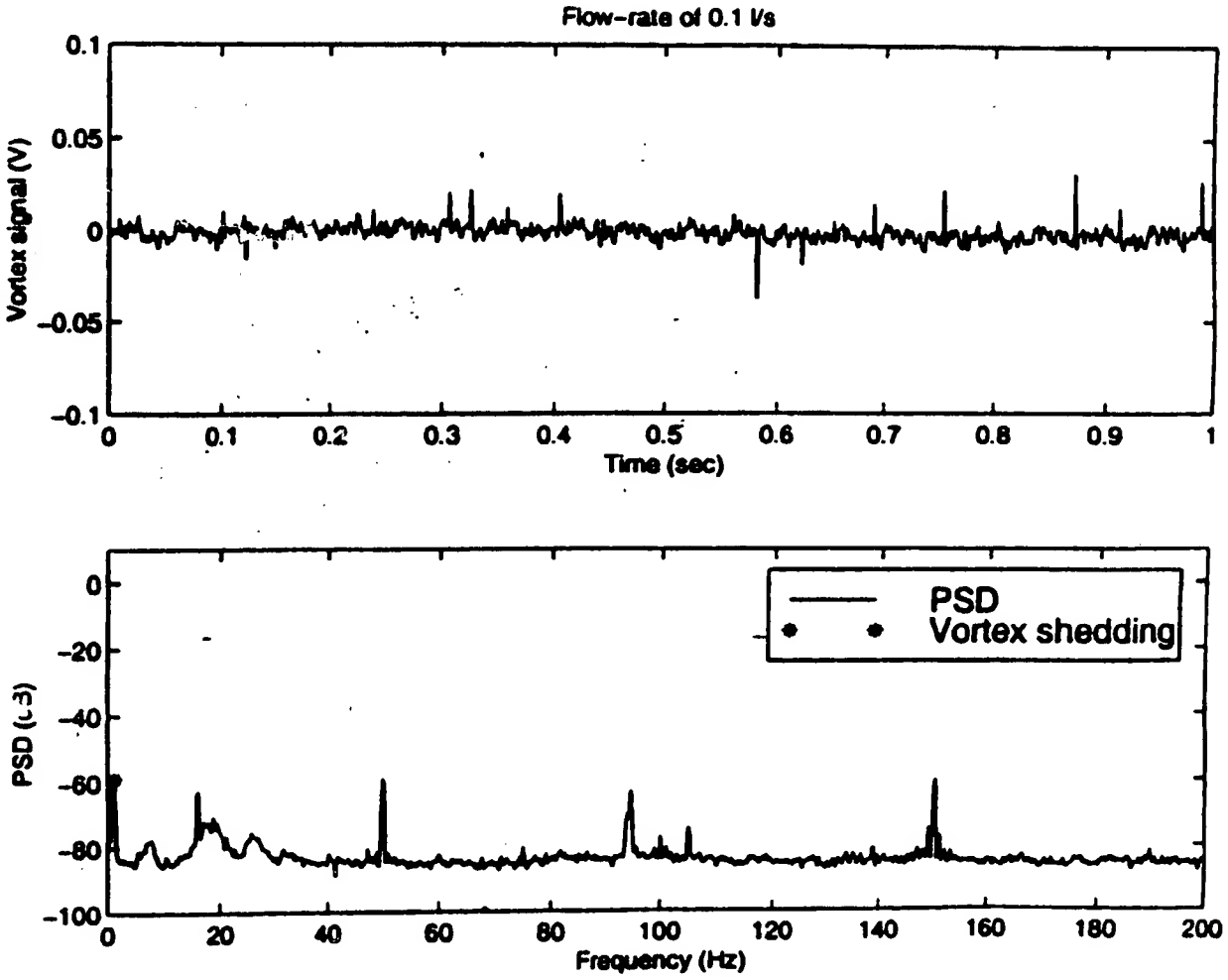
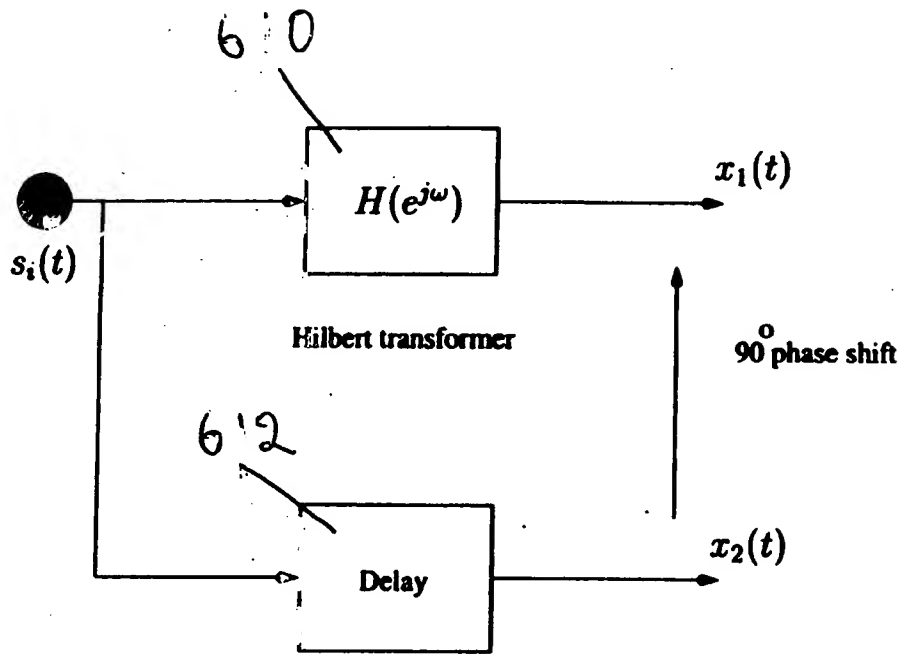


Figure 5



$\angle\ x_1(t)$ - $\angle\ x_2(t)$

Figure 6

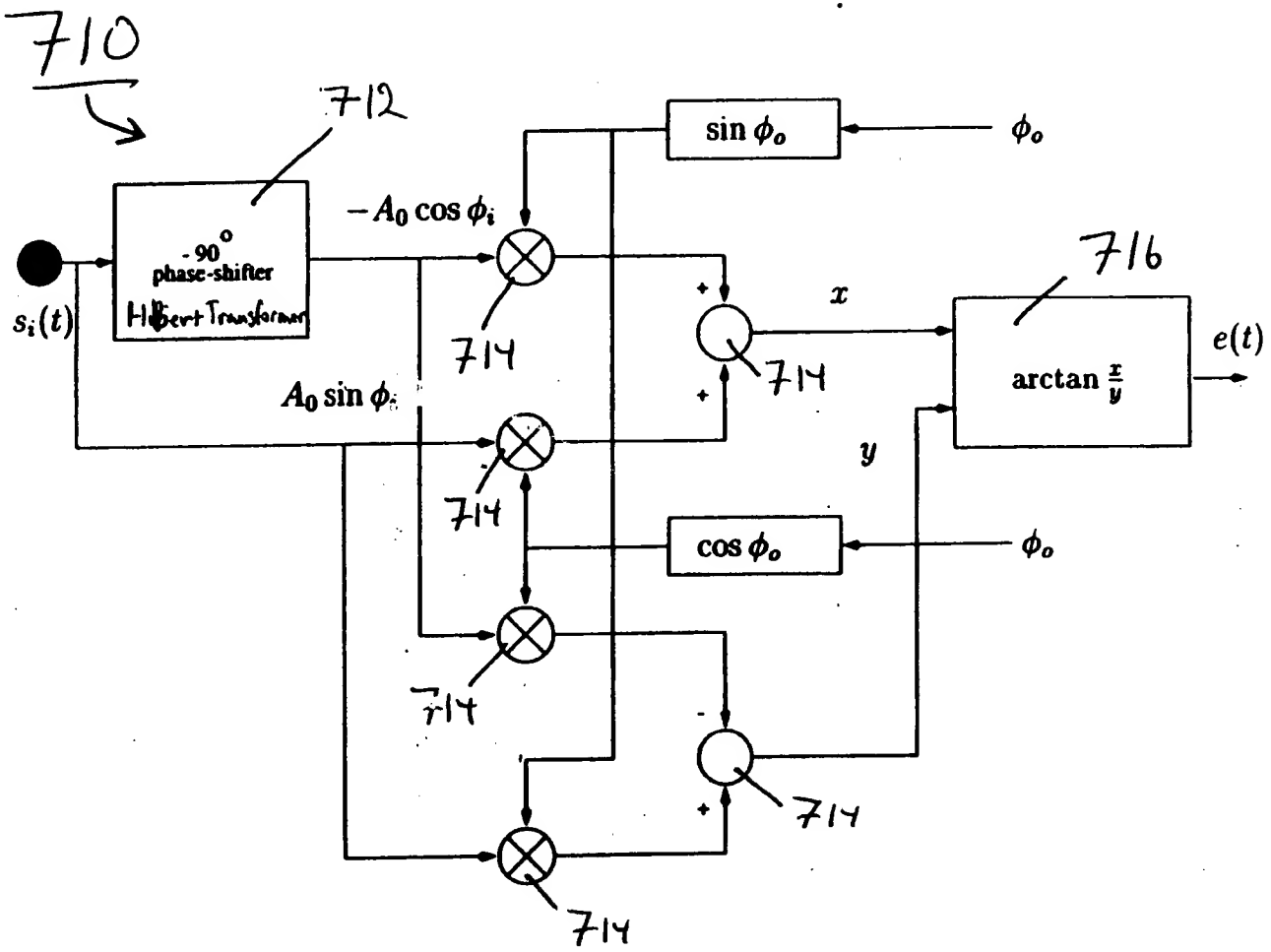


Figure 7

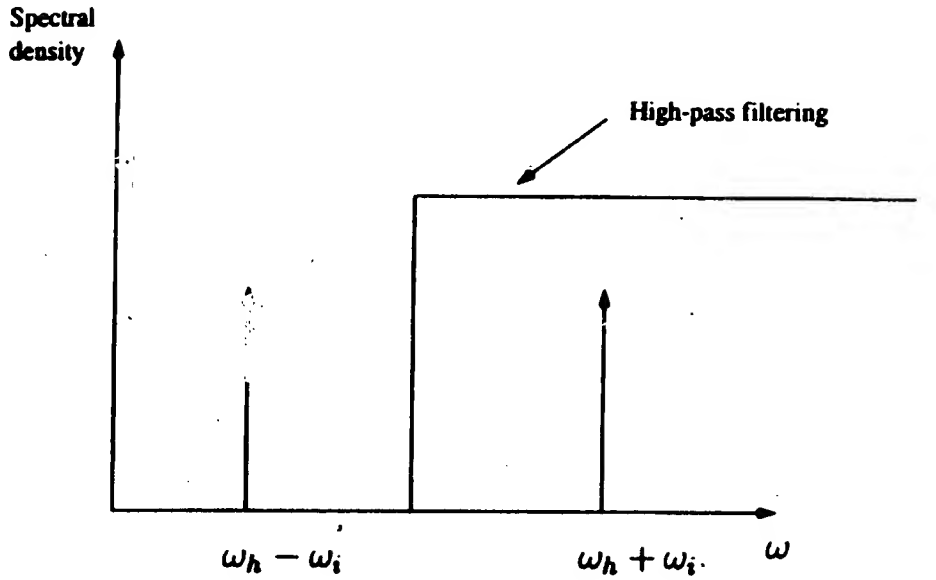


Figure 8

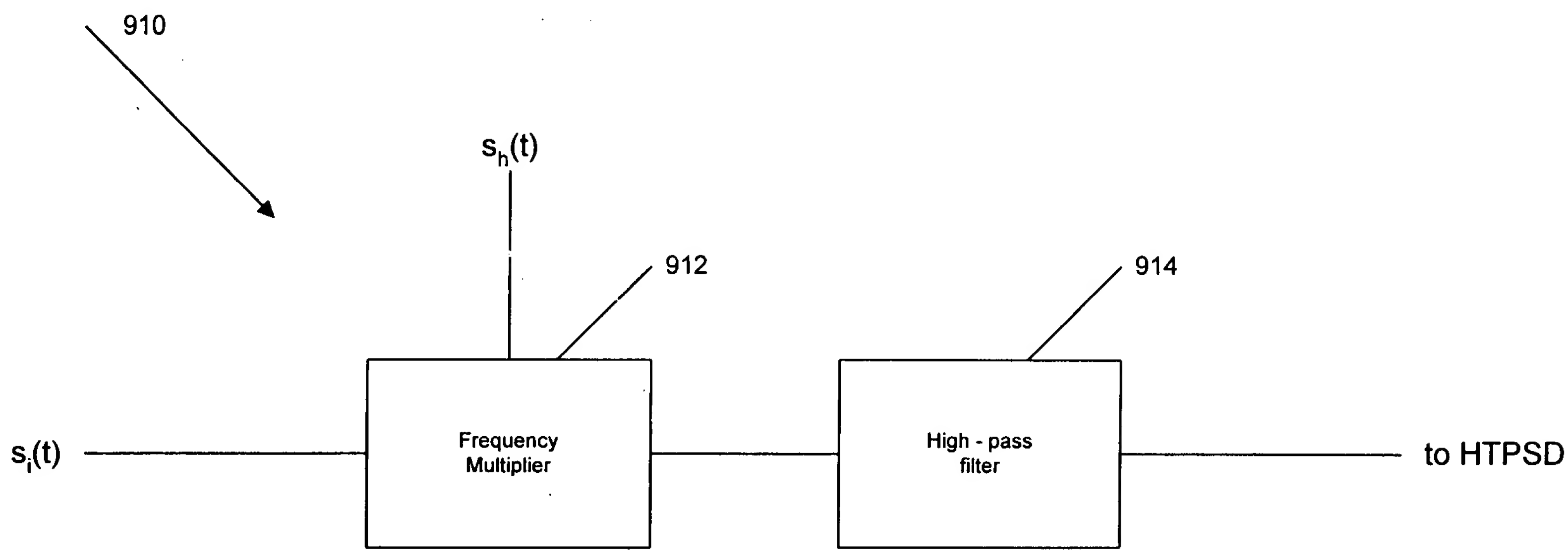

910
$s_h(t)$
912
914
$s_i(t)$
Frequency Multiplier
High - pass filter
to HTPSD

Figure 9

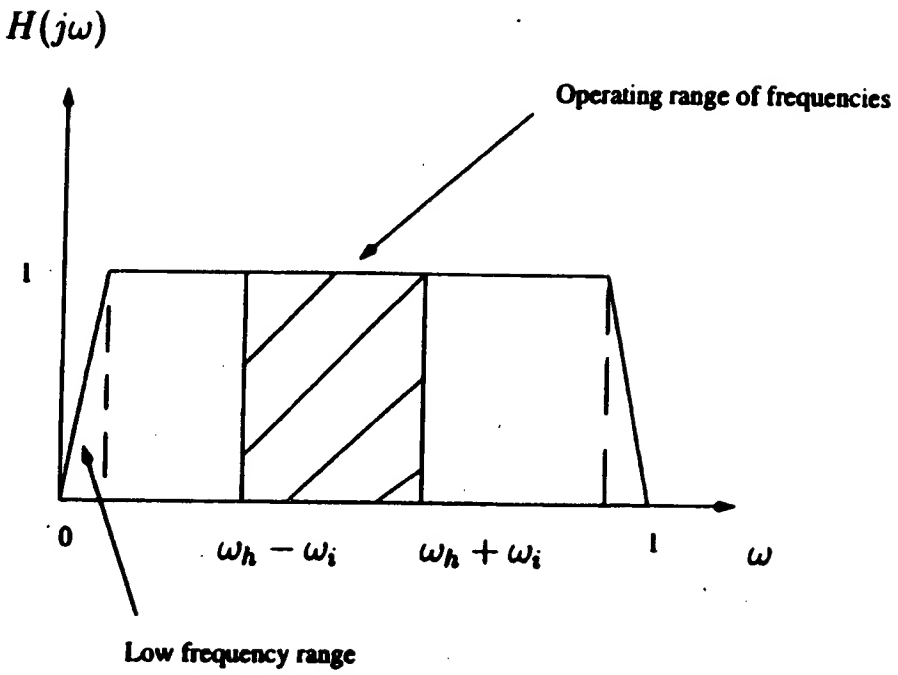


Figure 10

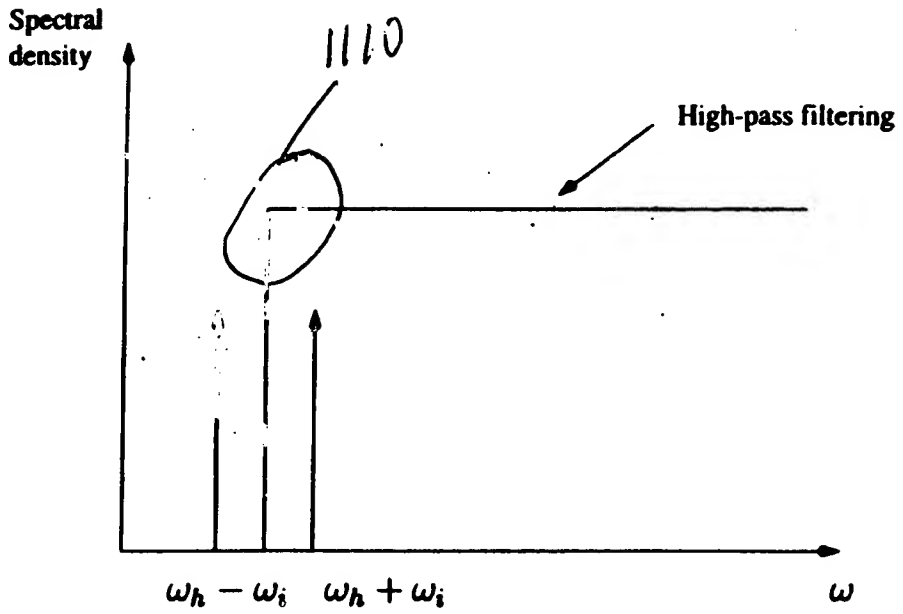


Figure 11

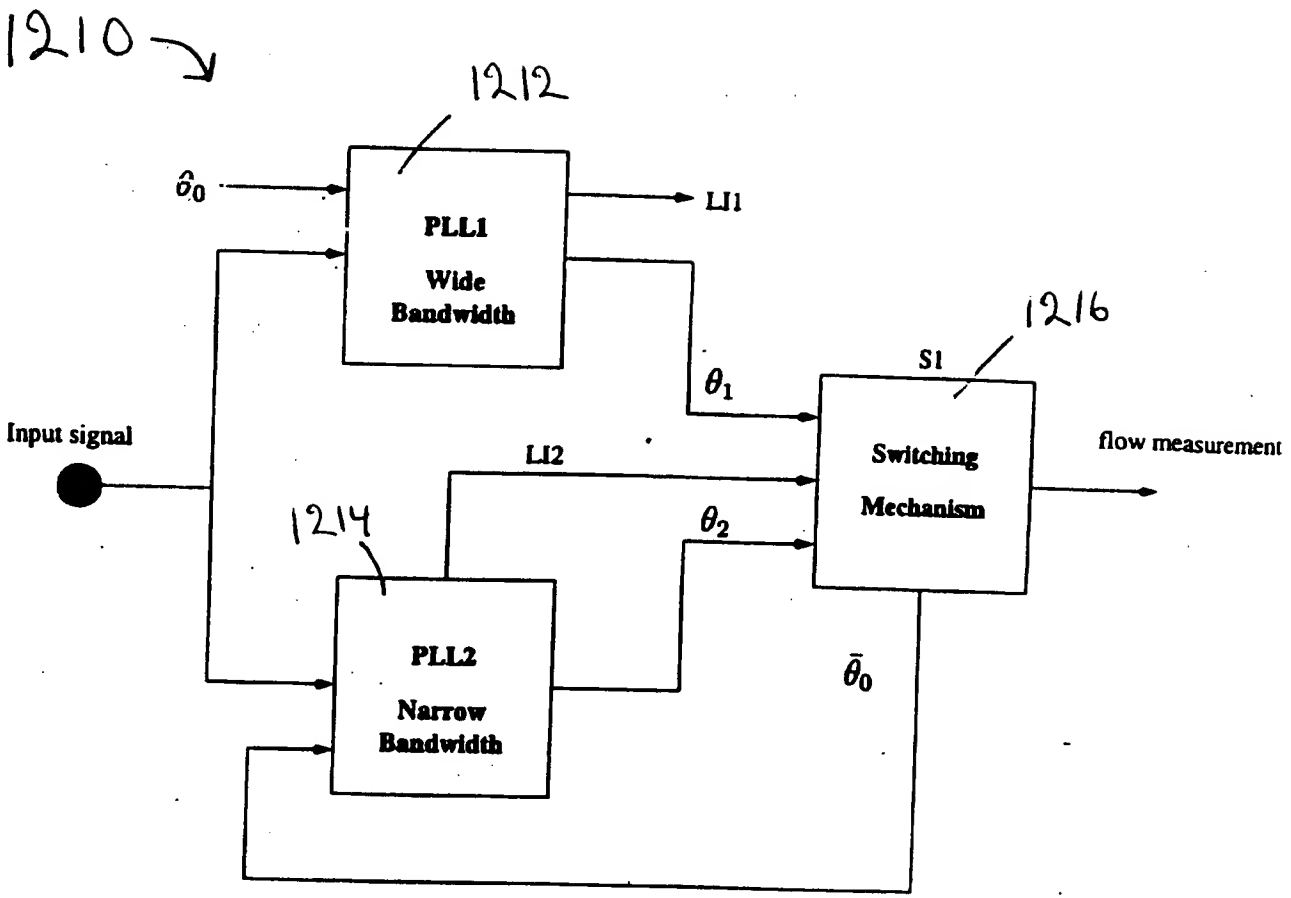


Figure 12

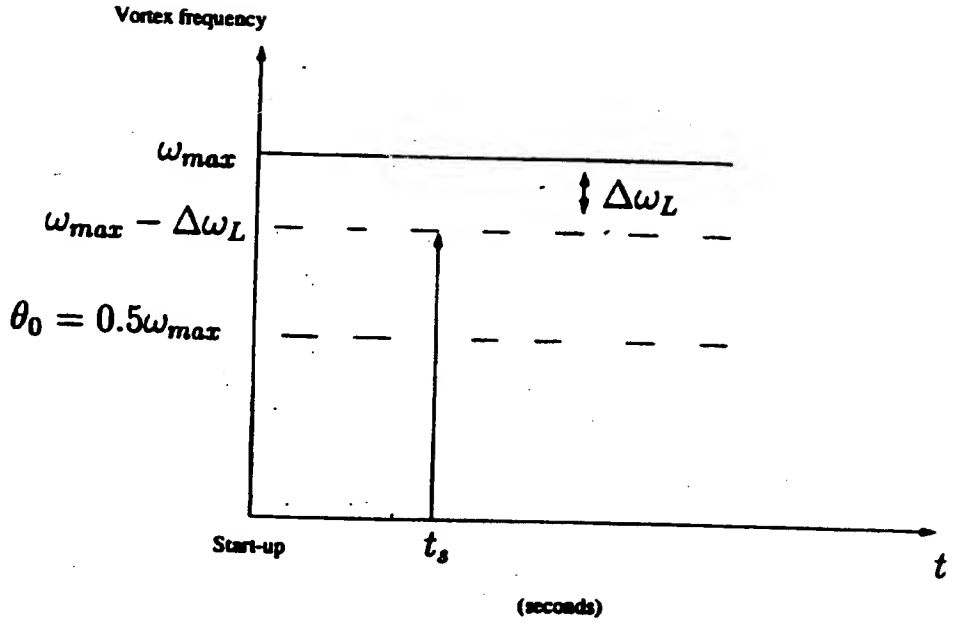


Figure 13

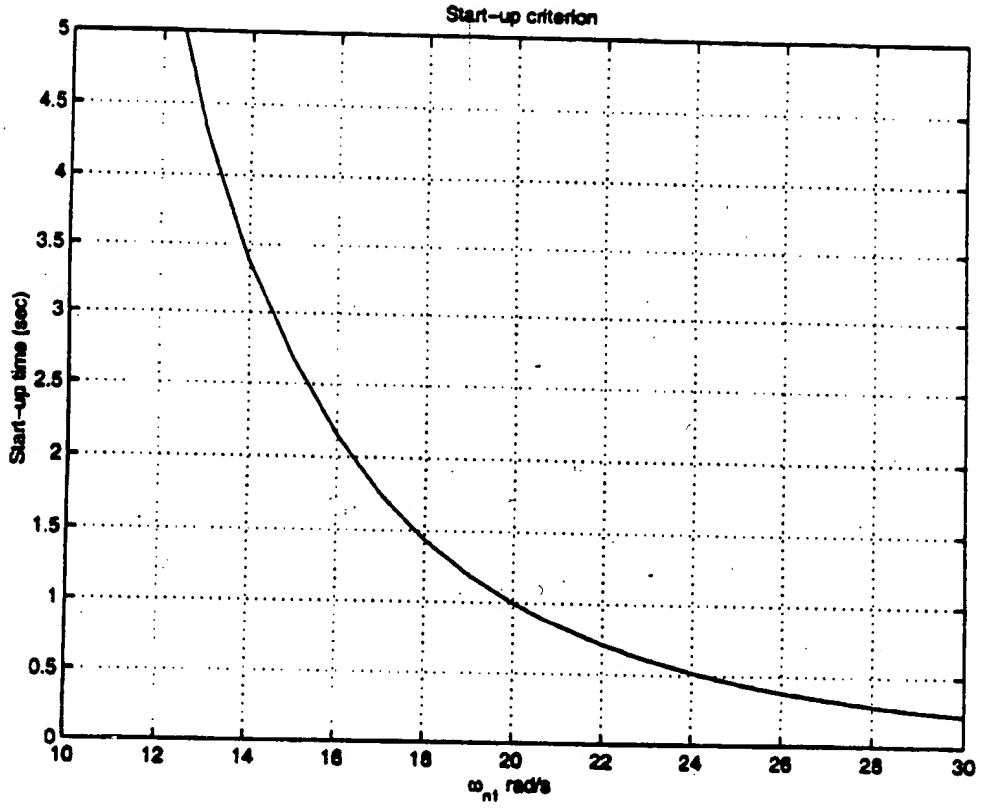

Start–up criterion
Start–up time (sec)
ω_{n1} rad/s
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
10
12
14
16
18
20
22
24
26
28
30

Figure 14.

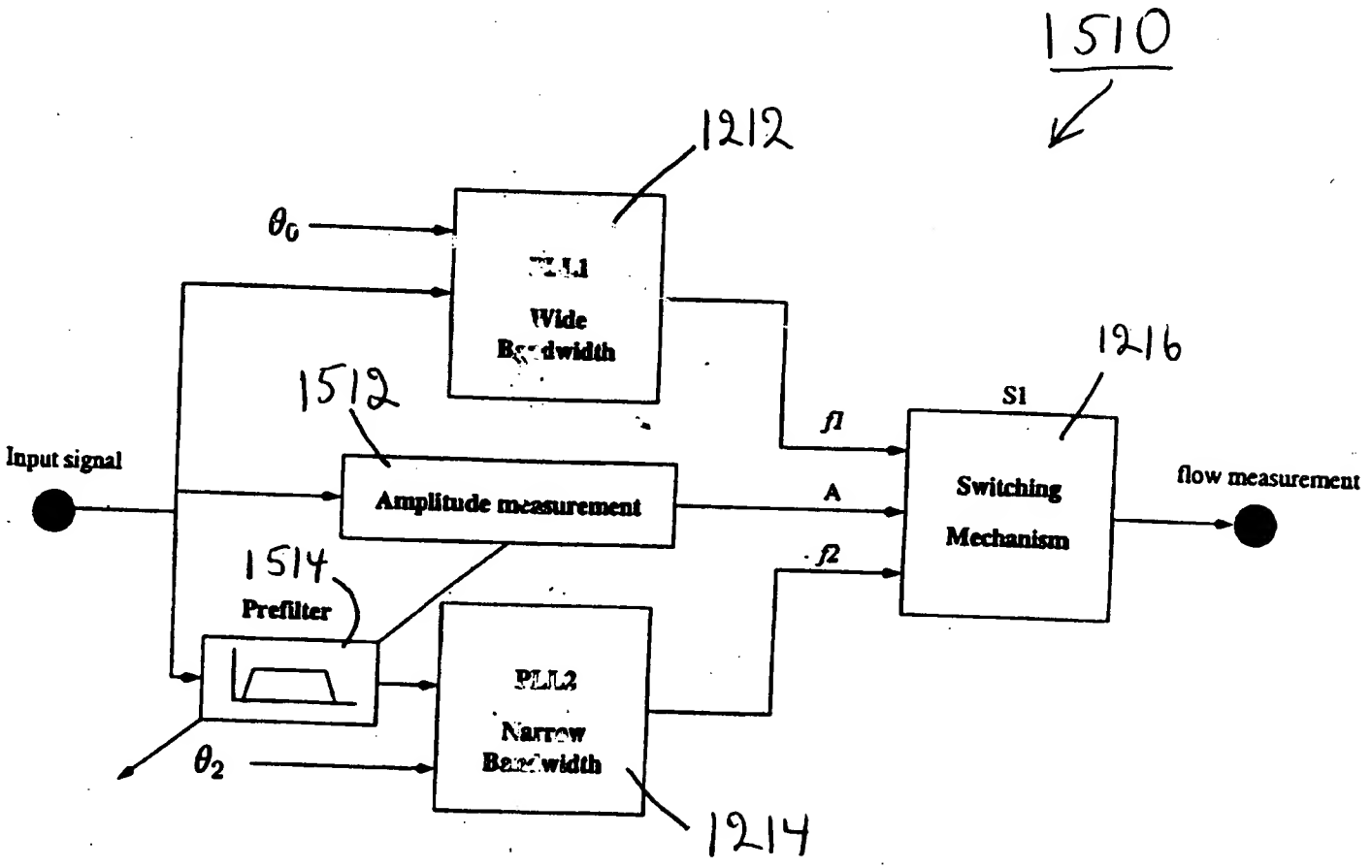


Figure 15

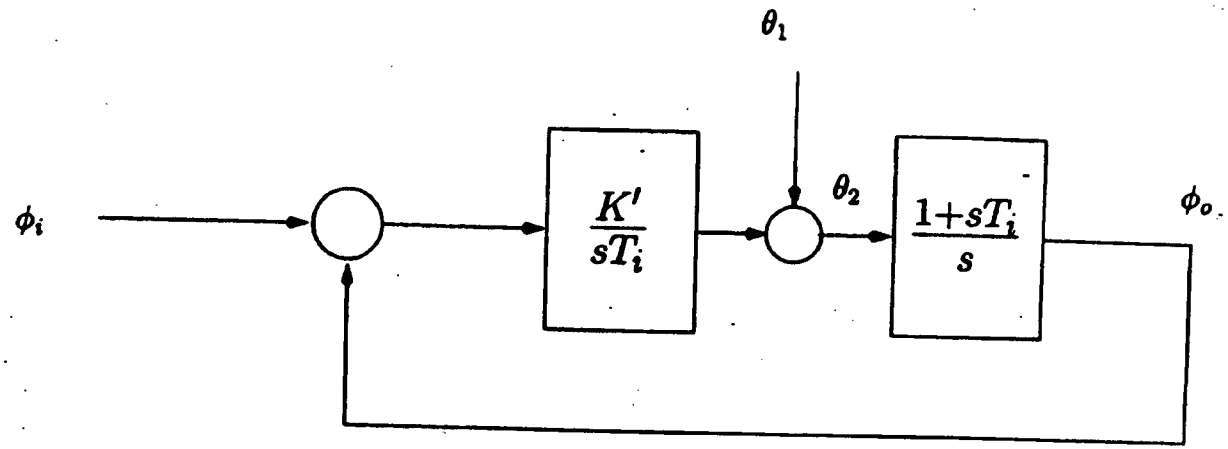


Figure 16

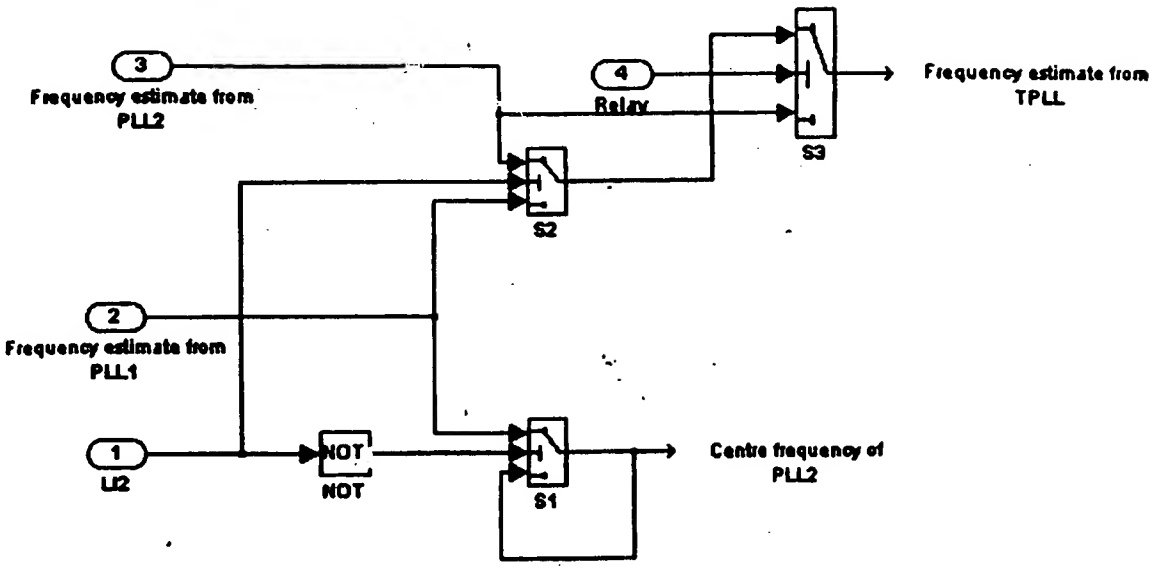

3
Frequency estimate from PLL2
4
Relay
Frequency estimate from TPLL
S3
S2
2
Frequency estimate from PLL1
1
U2
NOT
NOT
S1
Centre frequency of PLL2

Figure 17

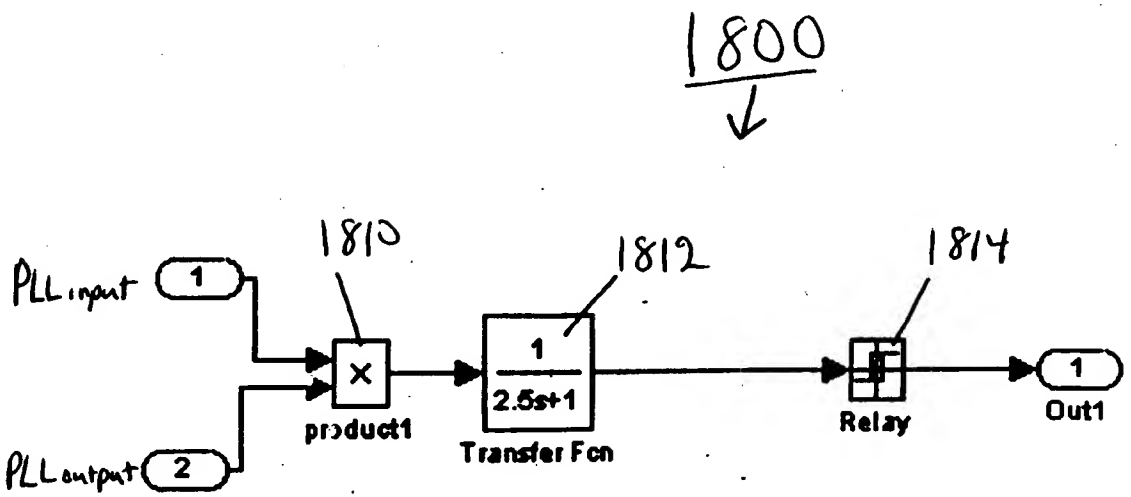


Figure 18

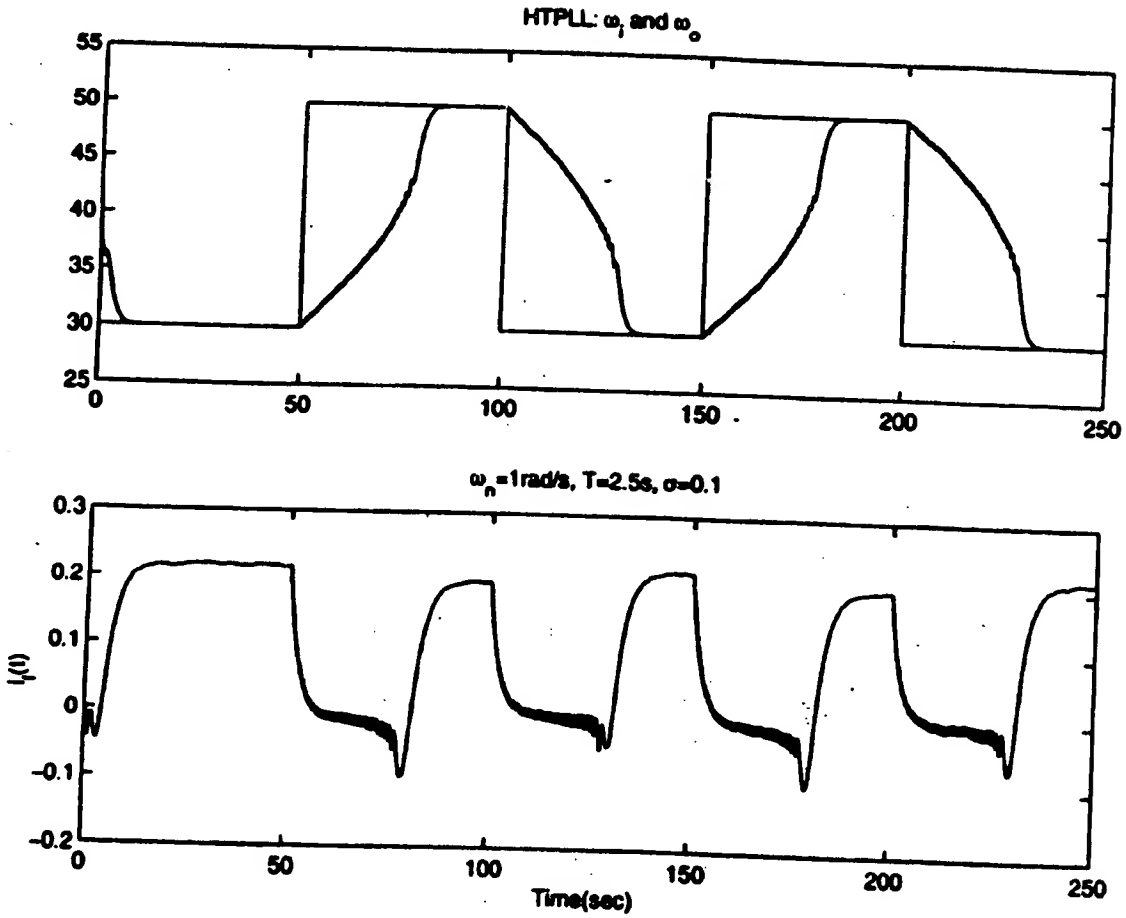


Figure 19

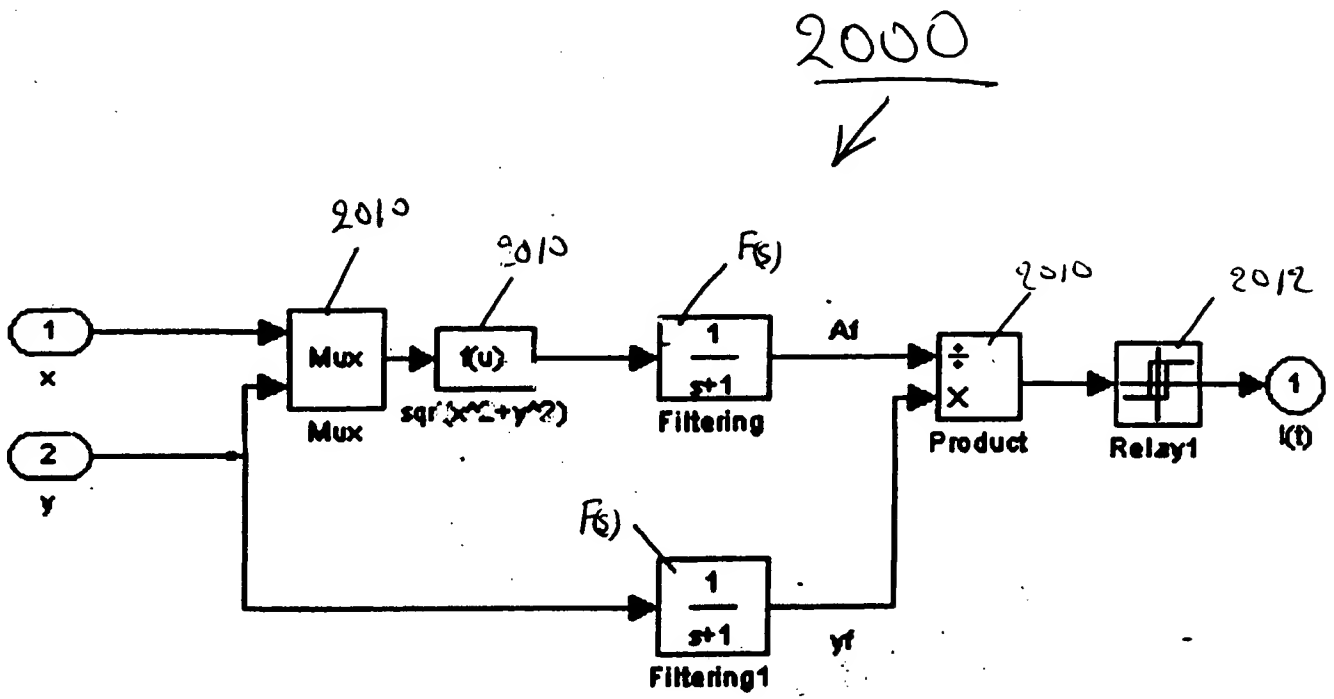


Figure 20

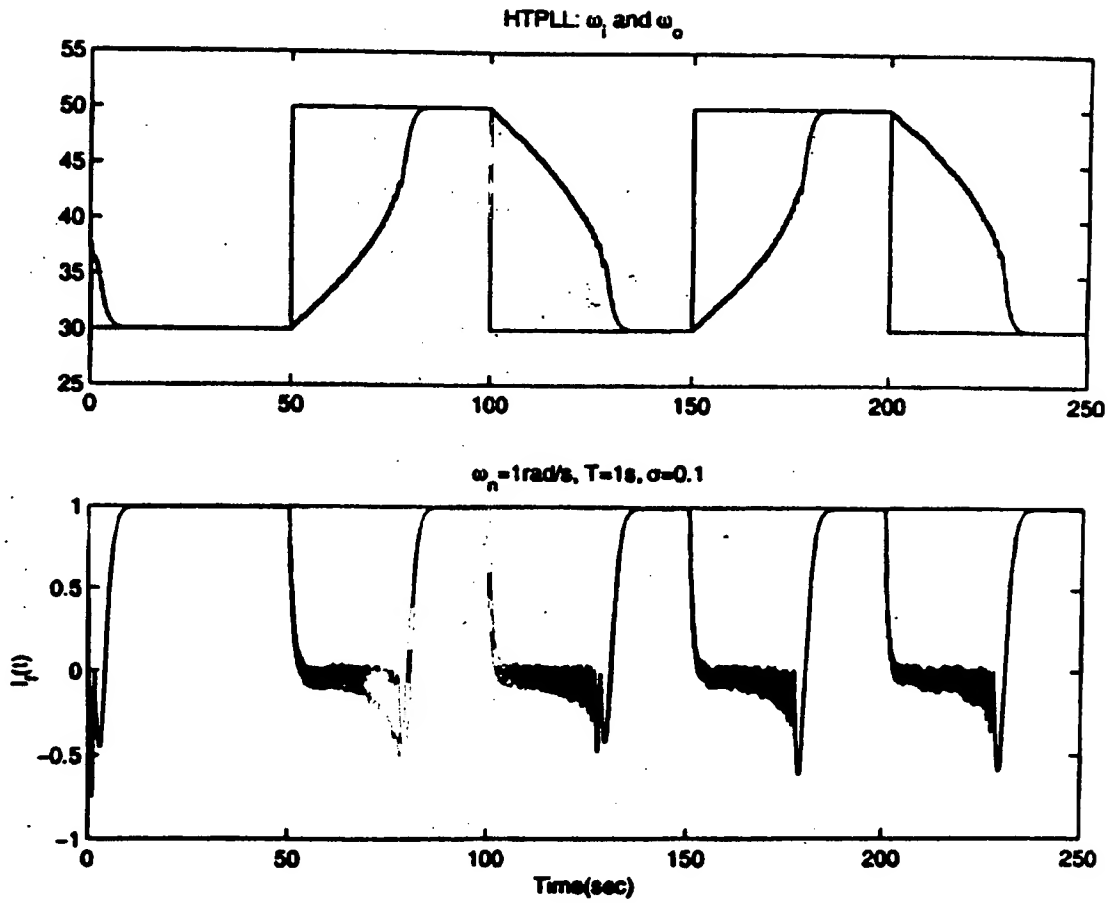


Figure 21

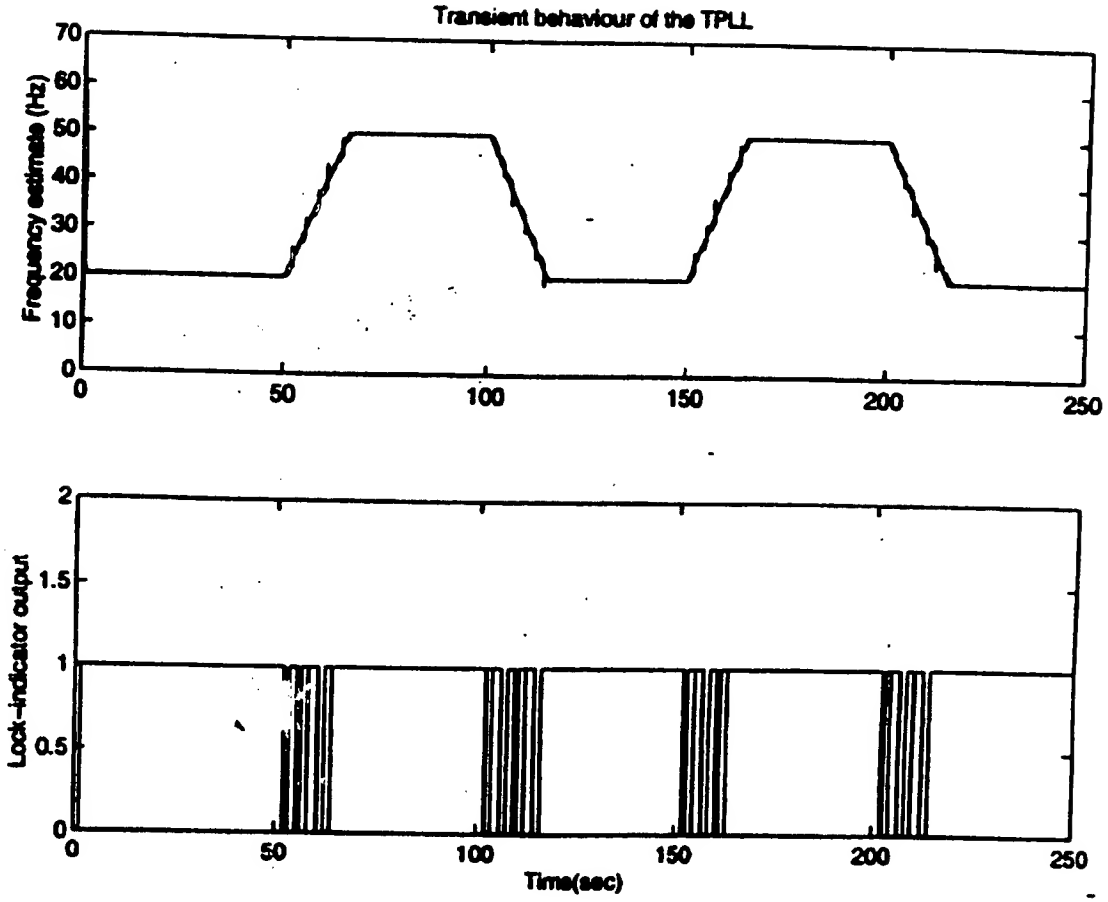


Figure 22

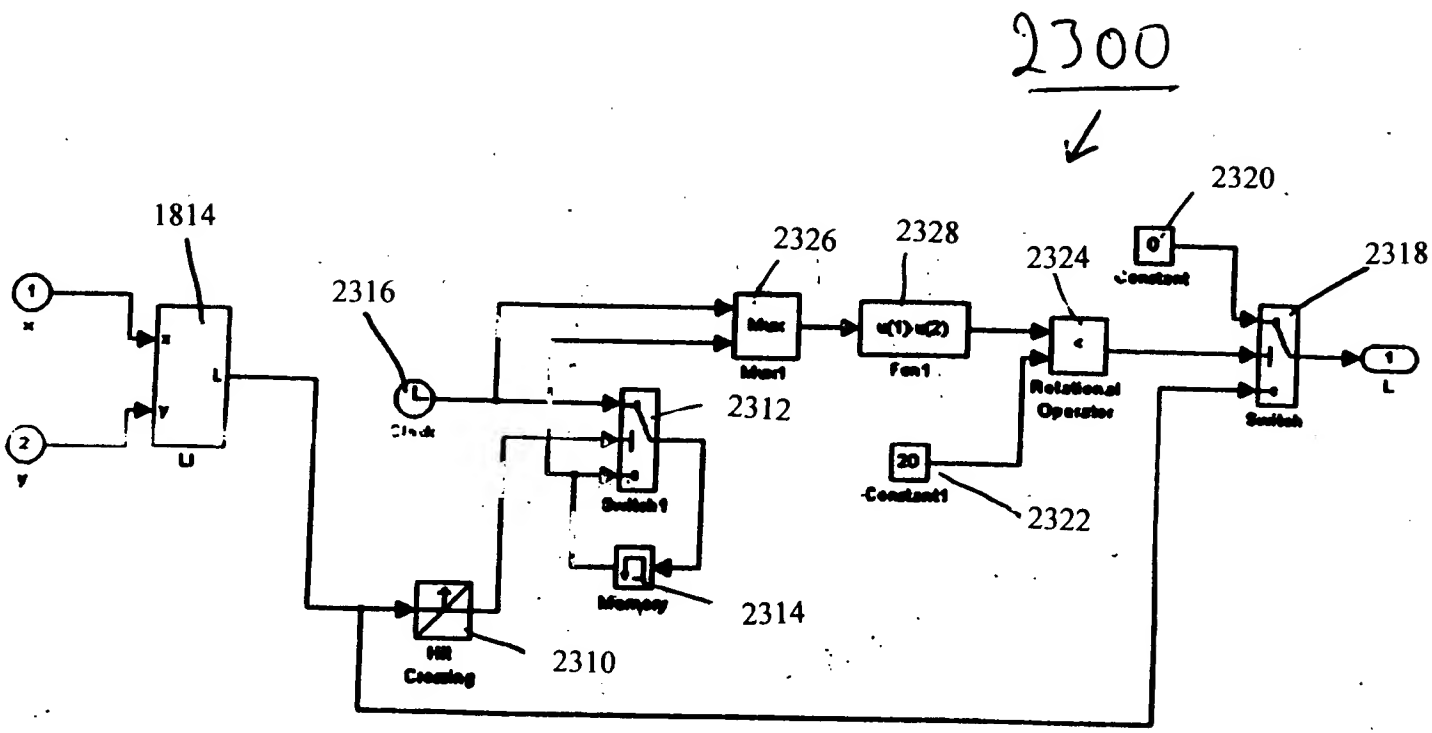


Figure 23

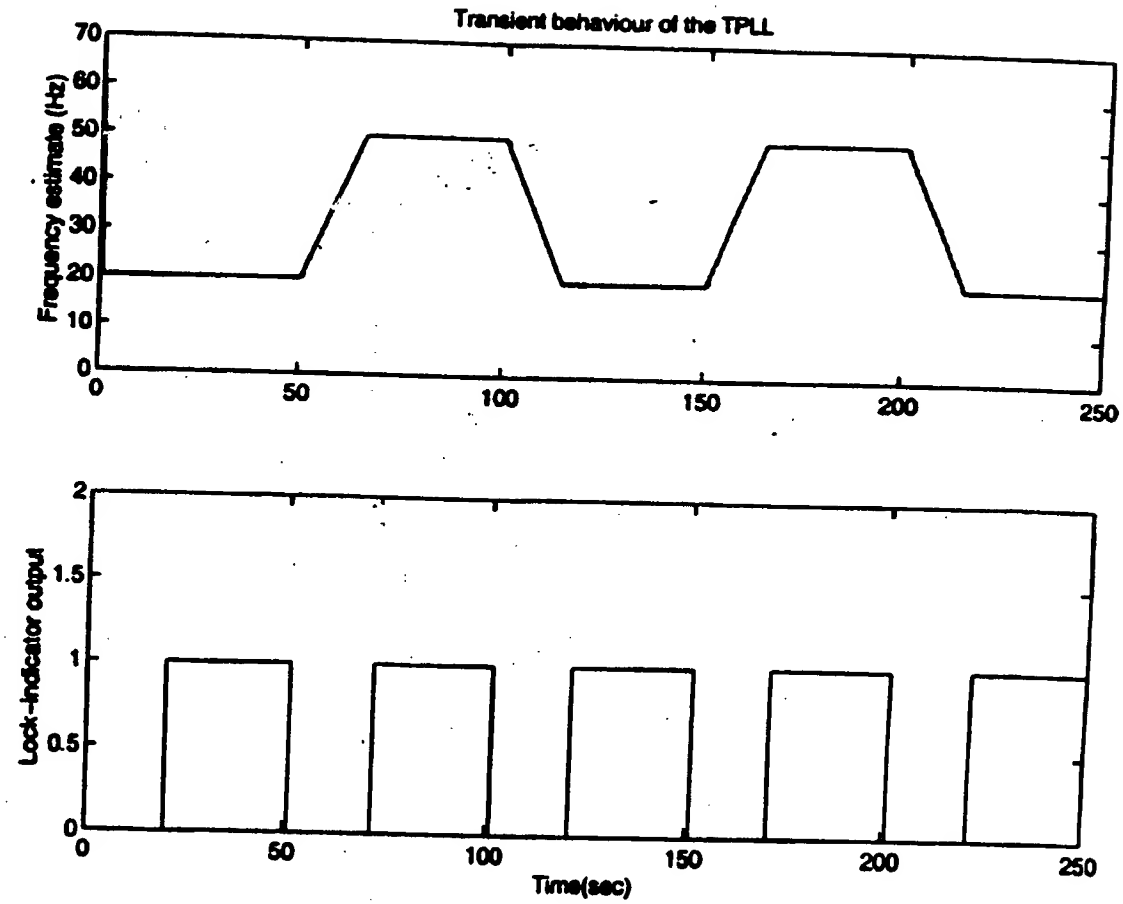


Figure 24

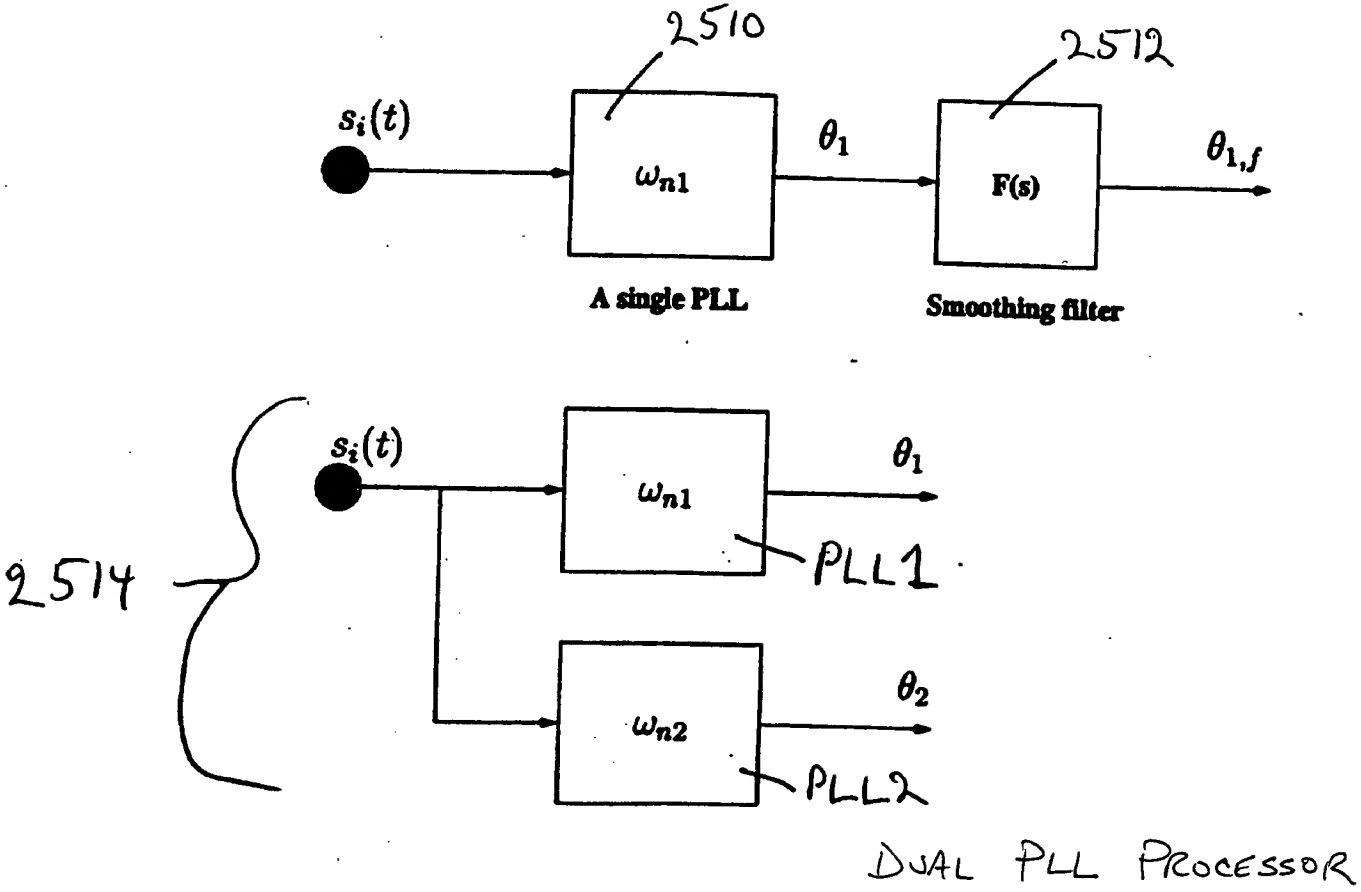


Figure 25

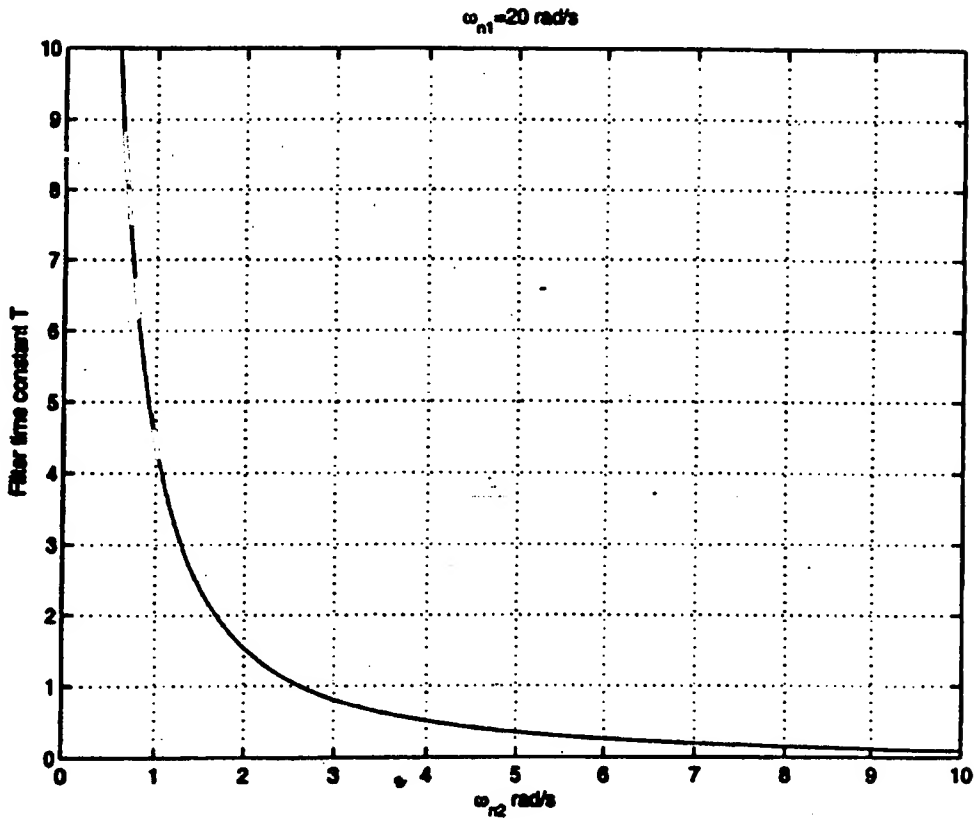


Figure 26

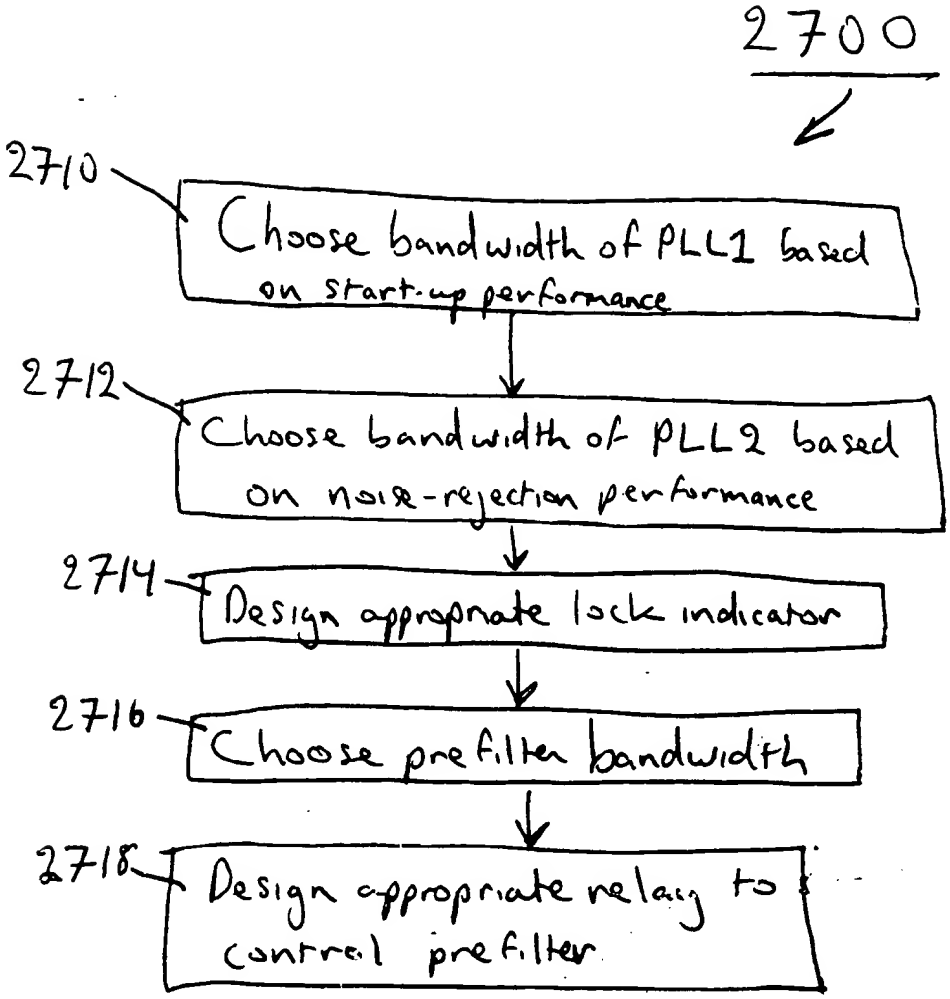

2700
2710
Choose bandwidth of PLL1 based on start-up performance
2712
Choose bandwidth of PLL2 based on noise-rejection performance
2714
Design appropriate lock indicator
2716
Choose prefilter bandwidth
2718
Design appropriate relay to control prefilter

Figure 27

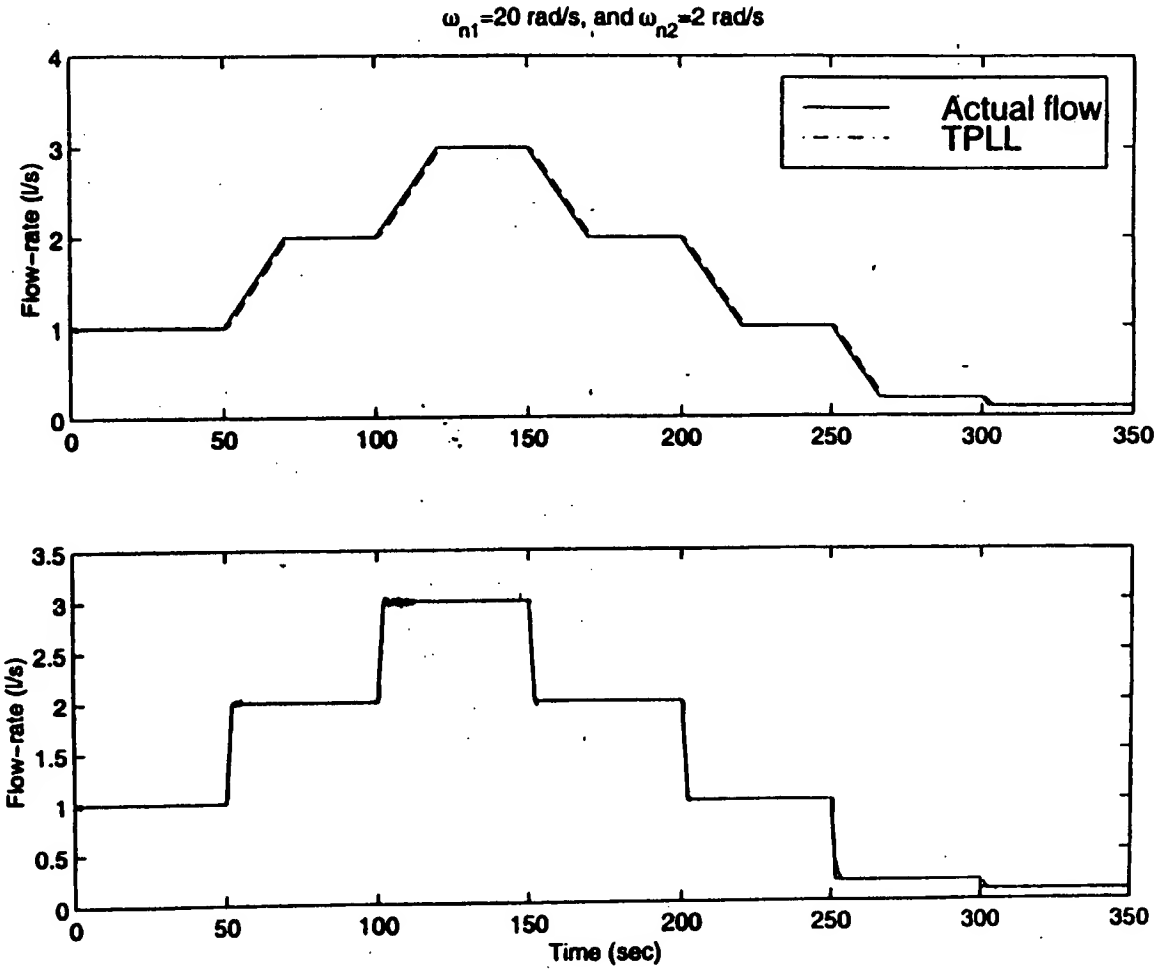


Figure 28

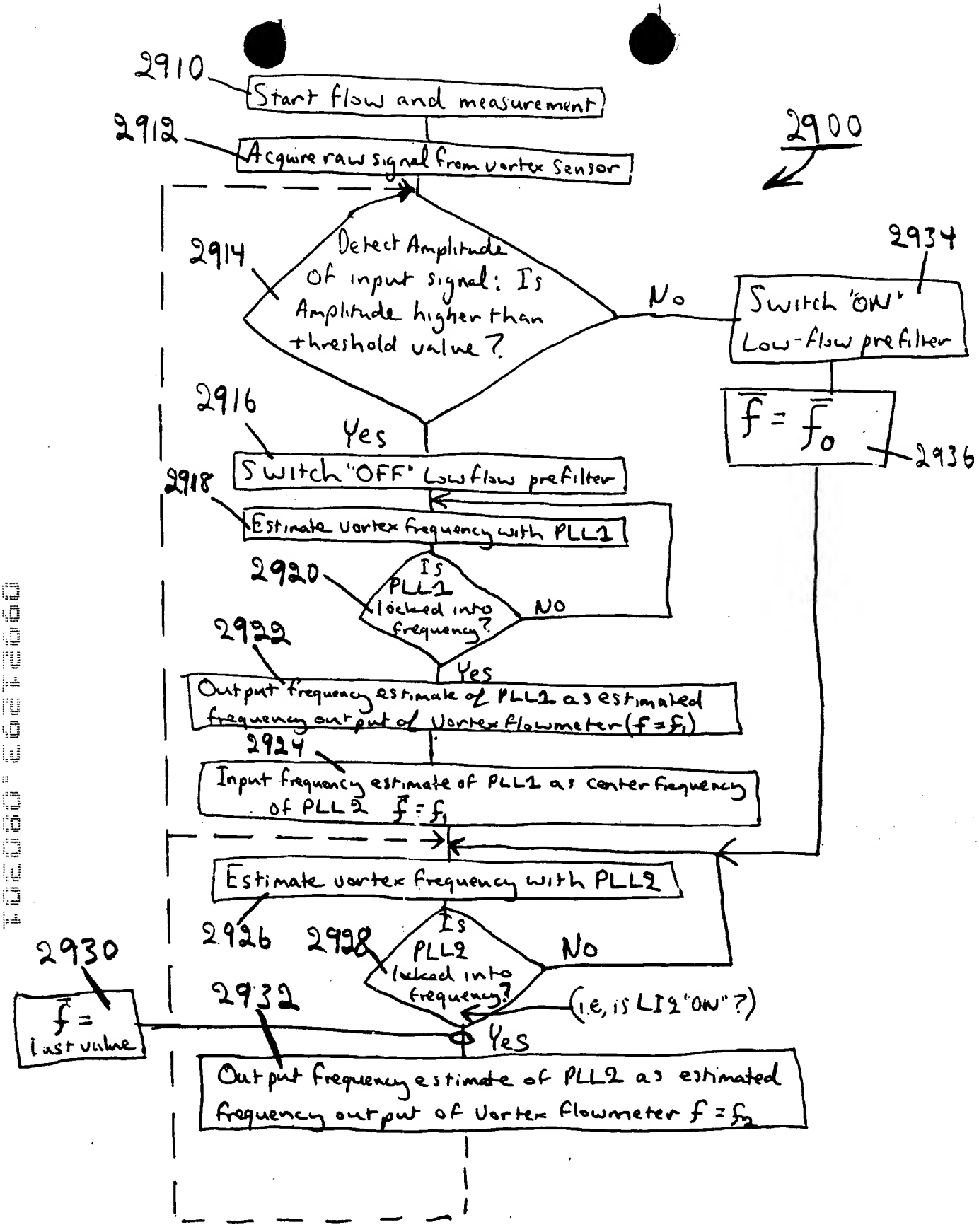

2900
2910
Start flow and measurement
2912
Acquire raw signal from vortex sensor
2914
Detect Amplitude of input signal: Is Amplitude higher than threshold value?
No
2934
Switch "ON" Low-flow prefilter
$\bar{f} = \bar{f}_0$
2936
Yes
2916
Switch "OFF" Low flow prefilter
2918
Estimate vortex frequency with PLL1
2920
Is PLL1 locked into frequency?
NO
Yes
2922
Output frequency estimate of PLL1 as estimated frequency output of Vortex flowmeter ($f = f_1$)
2924
Input frequency estimate of PLL1 as center frequency of PLL2 $\bar{f} = f_1$
Estimate vortex frequency with PLL2
2926
2928
Is PLL2 locked into frequency?
NO
(i.e, is LI2 "ON"?)
Yes
2930
$\bar{f}$ = last value
2932
Output frequency estimate of PLL2 as estimated frequency output of Vortex flowmeter $f = f_2$

Figure 29

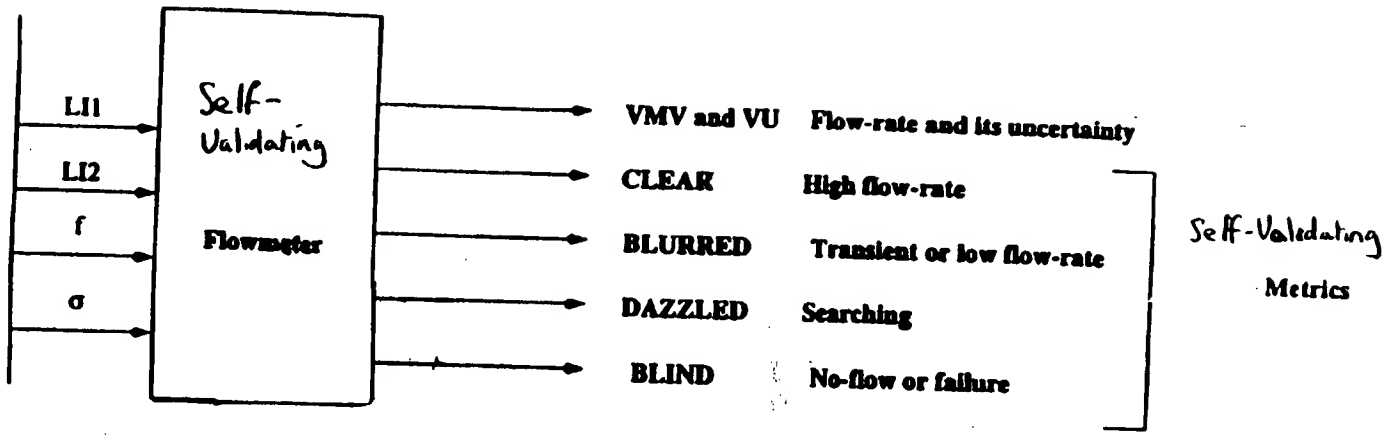


Figure 30